INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY

Atlanta, Georgia

EFFECT OF AGING TIME ON PROPERTIES OF TREATED AND UNTREATED PAPERS

IPST Project 3875

A Summary Report

to

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June 20, 1994

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INTRODUCTION

The Summary Report (April 4, 1994) on IPST Project 3875 gives the results of tests on control and treated papers. Results are included for unaged samples, and for samples which had been subjected to accelerated aging for various periods up to 30 days. The MIT Fold results in the Summary Report are for specimens which had been subjected to a tension of 1 kg. during the test. This Addendum Report gives MIT Fold results for specimens which had been subjected to a tension of 1/2 kg. during the test.

This Addendum Report also includes some retest data for Alkaline Reserve measurements, and computed values of Number Average Degree of Polymerization. The latter were computed from the Viscosity data given in the Summary Report.

TABLE I

MD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
0	Average	997	952	1185	1194	707	1302	N	N
	Std Dev	202	204	221	219	348	438		
								O	O
3	Average	555	681	666	689	792	964		
	Std Dev	143	172	133	158	354	363		
6	Average	362	466	364	955	490	839	S	S
	Std Dev	78	96	85	197	183	347		
								A	A
10	Average	190	474	64	725	242	796		
	Std Dev	101	143	28	121	90	245	M	M
13	Average	43	365	9	525	205	498	P	P
	Std Dev	18	125	1	132	118	195		
								L	L
17	Average	12	318	5	488	310	605		
	Std Dev	3	145	1	73	98	255	E	E
25	Average	3	196	1	372	46	362		
	Std Dev	1	54	0	116	21	206		
31	Average	1	203	1	150	47	271		
	Std Dev	1	66	0	50	21	121		

REGRESSION STATISTICS (based on log fold data)

R Squared	0.982	0.925	0.915	0.886	0.900	0.947
Coefficient	-0.103	-0.021	-0.110	-0.024	-0.042	-0.021
Std Err	0.0057	0.0025	0.0138	0.0036	0.0058	0.0020
Constant	3.06	2.88	2.94	3.06	2.94	3.07

TABLE II

CD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
0	Average	281	371	358	304	220	235	N	N
	Std Dev	98	108	99	77	166	115		
								O	O
3	Average	225	289	254	248	159	294		
	Std Dev	59	90	43	73	61	200		
6	Average	266	232	166	359	101	340	S	S
	Std Dev	64	41	41	49	69	202		
								A	A
10	Average	88	199	83	183	85	179		
	Std Dev	23	47	15	61	62	87	M	M
13	Average	72	179	32	186	63	173	P	P
	Std Dev	38	69	7	52	29	66		
								L	L
17	Average	34	183	30	176	51	154		
	Std Dev	9	61	5	61	19	99	E	E
25	Average	4	77	7	151	16	131		
	Std Dev	2	46	5	32	6	59		
31	Average	3	102	2	113	11	138		
	Std Dev	1	30	0	21	3	76		

REGRESSION STATISTICS (based on log fold data)

R Squared	0.962	0.888	0.988	0.808	0.986	0.697
Coefficient	-0.072	-0.020	-0.074	-0.014	-0.042	-0.012
Std Err	0.0058	0.0028	0.0034	0.0027	0.0021	0.0032
Constant	2.65	2.52	2.62	2.48	2.33	2.44

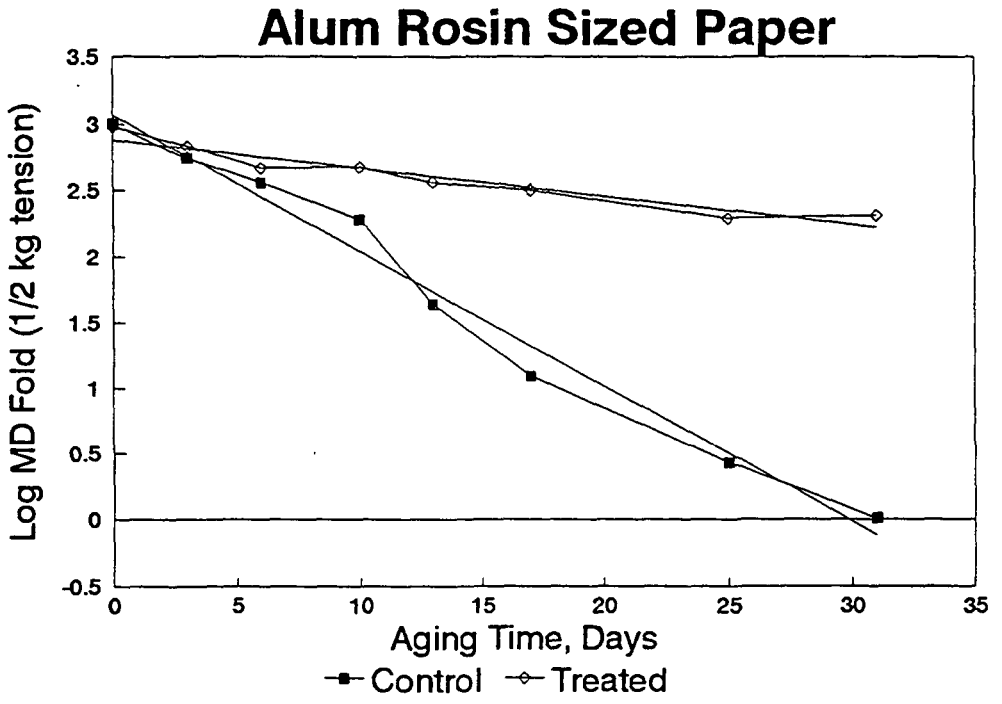

Fig. 1-AR Effect of Aging Time on log MD Folding Endurance.

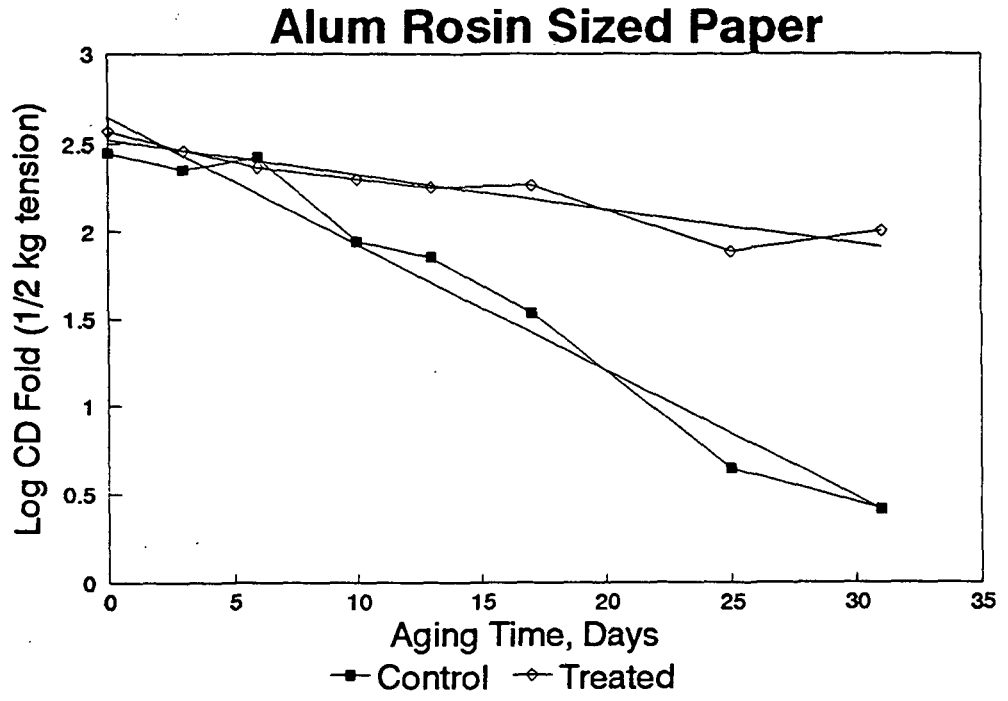

Fig. 2-AR Effect of Aging Time on log CD Folding Endurance.

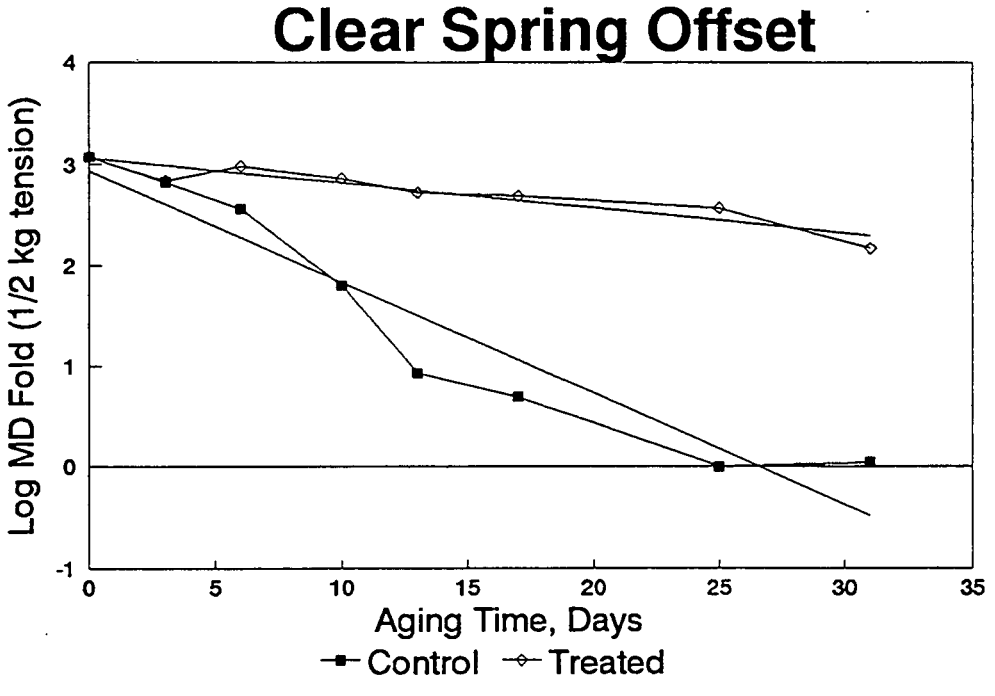

Fig. 1-CS Effect of Aging Time on log MD Folding Endurance.

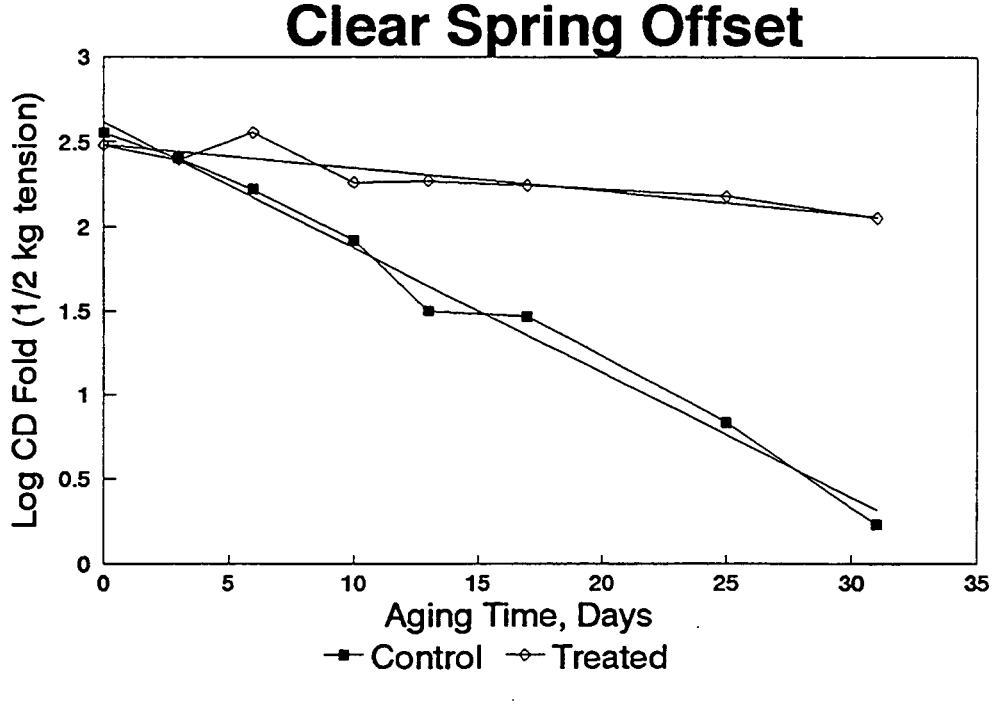

Fig. 2-CS Effect of Aging Time on log CD Folding Endurance.

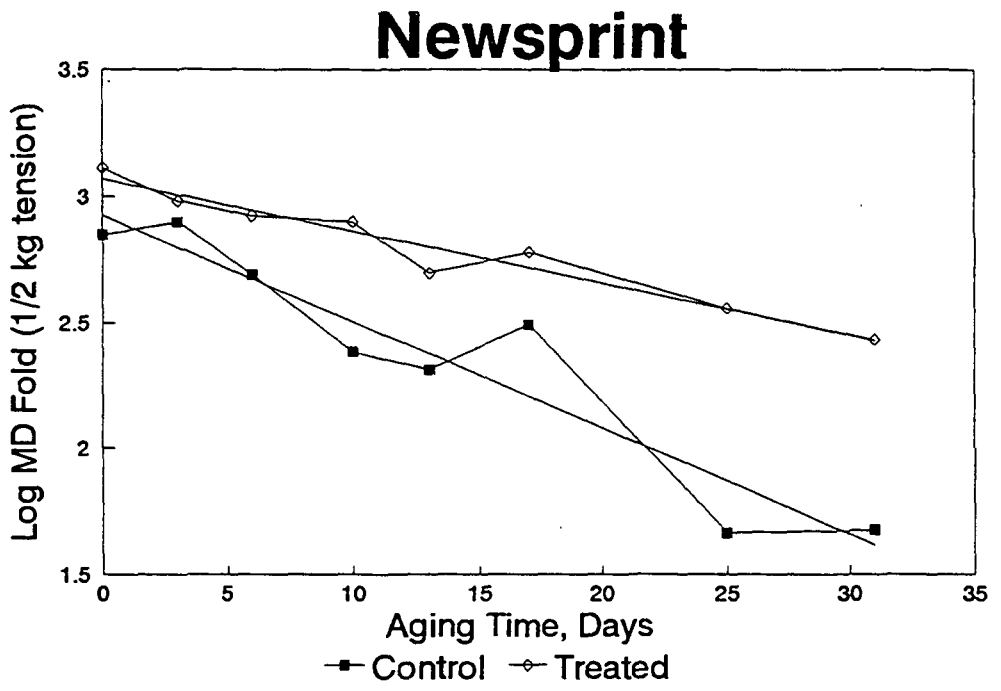

Fig. 1-NP Effect of Aging Time on log MD Folding Endurance.

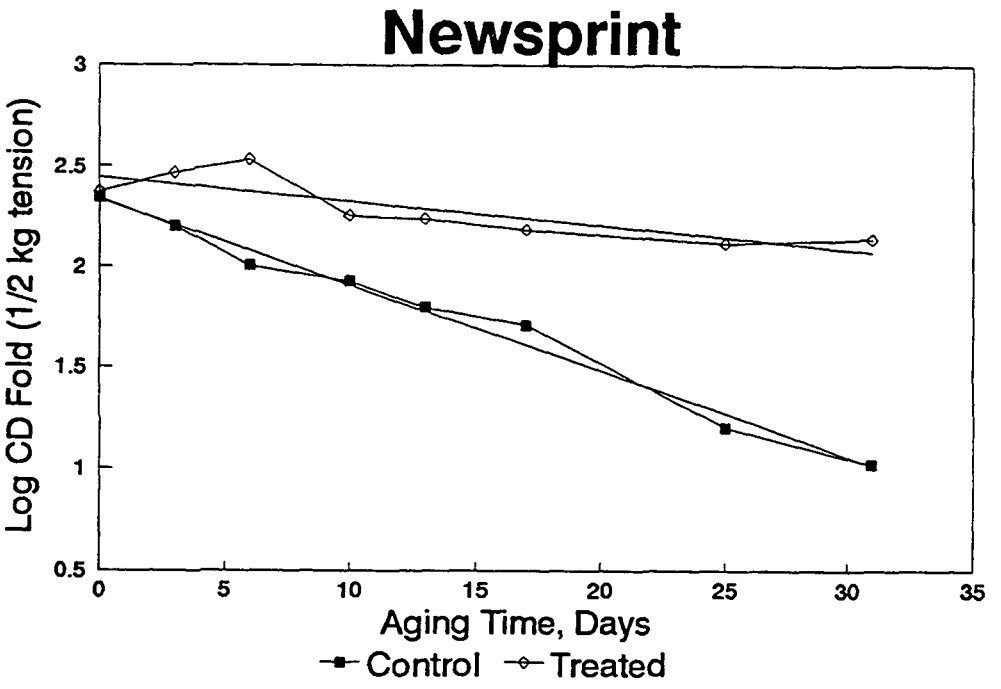

Fig. 2-NP Effect of Aging Time on log CD Folding Endurance.

TABLE III

ALKALINE RESERVE DATA (% $CaCO_3$)

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
0	Average	0.59	1.10	0.00	0.86	0.14	1.35	8.21	8.50
	Range	0.00	0.05	0.00	0.06	0.05	0.11	0.19	0.10
3	Average	0.69	1.57	0.08	0.77	0.00		7.97	8.46
	Range	0.21	0.12	0.16	0.15	0.00		0.33	0.06
6	Average	0.79	1.22	0.11	0.97	0.00	1.36	8.09	8.33
	Range	0.05	0.11	0.11	0.05	0.00	0.10	0.05	0.01
10	Average	0.62	1.47	0.08	0.75	0.03	1.21	8.23	8.48
	Range	0.05	0.04	0.05	0.04	0.05	0.01	0.11	0.00
13	Average	0.53	1.42	0.08	0.87	0.00	1.42	8.13	8.86
	Range	0.00	0.11	0.16	0.05	0.00	0.10	0.06	0.11
17	Average	0.60	1.37	0.05	0.95	0.00	1.25	8.00	8.57
	Range	0.04	0.01	0.10	0.01	0.00	0.05	0.00	0.13
24	Average	0.73	1.26	0.10	0.88	0.08		8.11	8.76
	Range	0.10	0.11	0.10	0.00	0.05		0.12	0.04
30	Average	0.69	1.38	0.06	0.76	0.00	1.19	8.04	8.80
	Range	0.01	0.05	0.11	0.05	0.00	0.11	0.06	0.07

REGRESSION STATISTICS

R Squared	0.019	0.012	0.068	0.012	0.062	0.016	0.057	0.529
Coefficient	0.001	0.002	0.001	0.000	-0.001	-0.001	-0.002	0.013
Std Err	0.0033	0.0058	0.0012	0.0033	0.0019	0.0049	0.0035	0.0051
Constant	0.64	1.33	0.06	0.86	0.05	1.35	8.12	8.42

NOTE: There was insufficient sample to retest the 3- and 24-day aged material for Sample NPT.

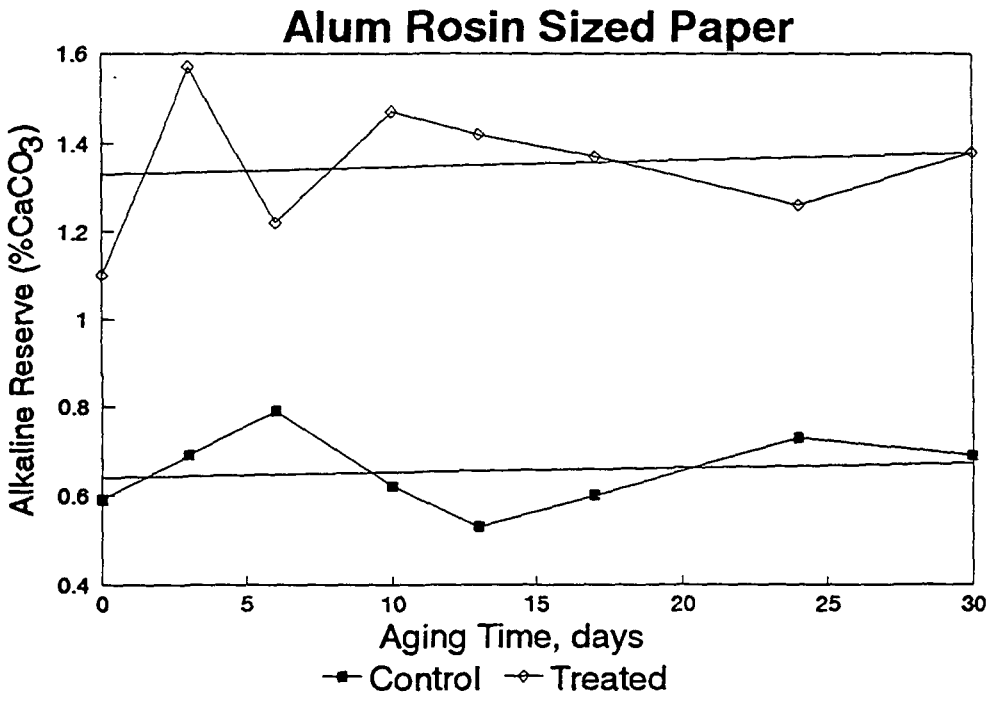

Fig. 3-AR Effect of Aging Time on Alkaline Reserve.

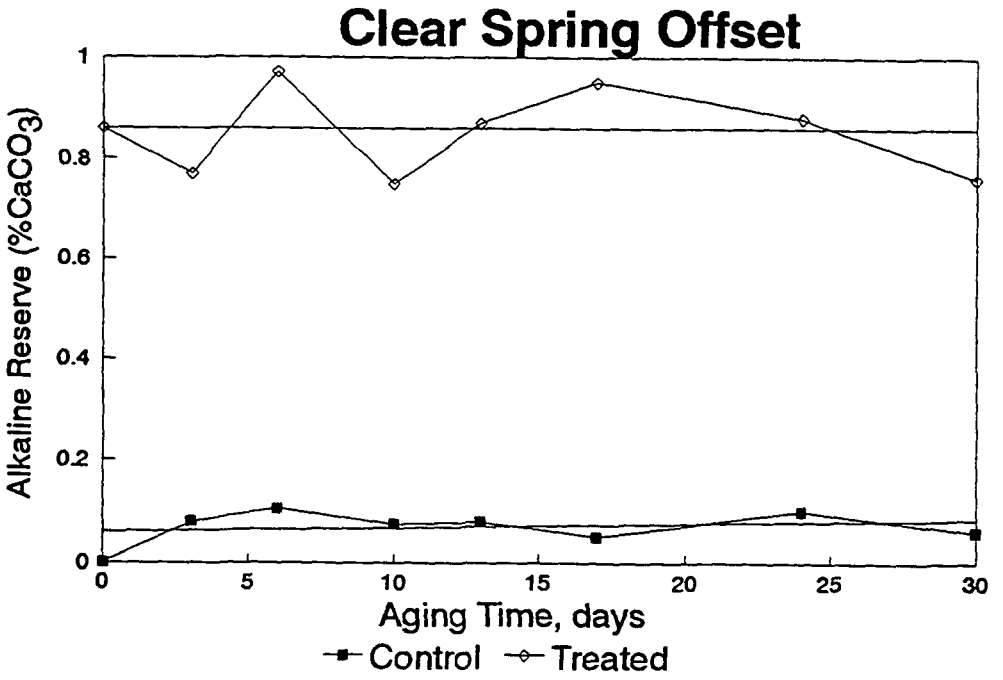

Fig. 3-CS Effect of Aging Time on Alkaline Reserve.

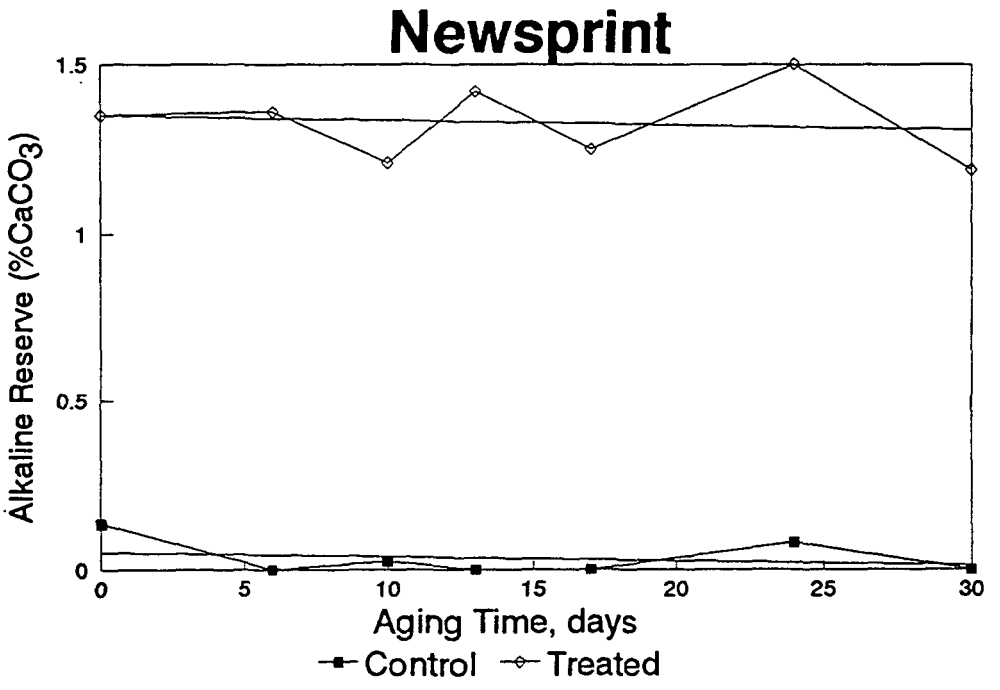

Fig. 3-NP Effect of Aging Time on Alkaline Reserve.
Note: There was insufficient material to retest the 3- and 24-day treated samples. The plotted data points for these are calculated from the regression constants.

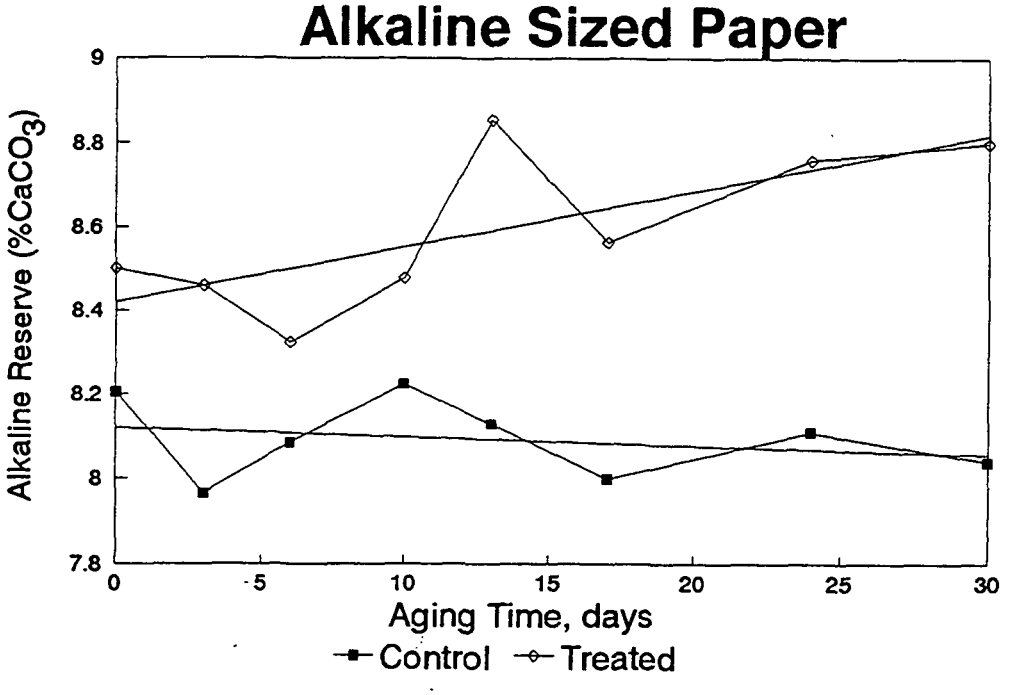

Fig. 3-AS Effect of Aging Time on Alkaline Reserve.

TABLE IV

Number Average Degree of Polymerization

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
0	Average	484	472	840	783	388	350	564	514
3	Average	381	402	610	673	259	287	484	498
6	Average	341	376	525	616	183	230	488	526
10	Average	293	348	469	568	125	206	484	496
13	Average	267	312	403	519	160	125	482	462
17	Average	242	349	366	484	120	201	428	434
24	Average	211	269	326	402	86	129	452	420
30	Average	188	253	302	393	82	125	438	413

NOTE: Number average degree of polymerization (DPn) calculated as follows:

$$DPn = 961.38 * \log(\text{viscosity}) - 245.3$$

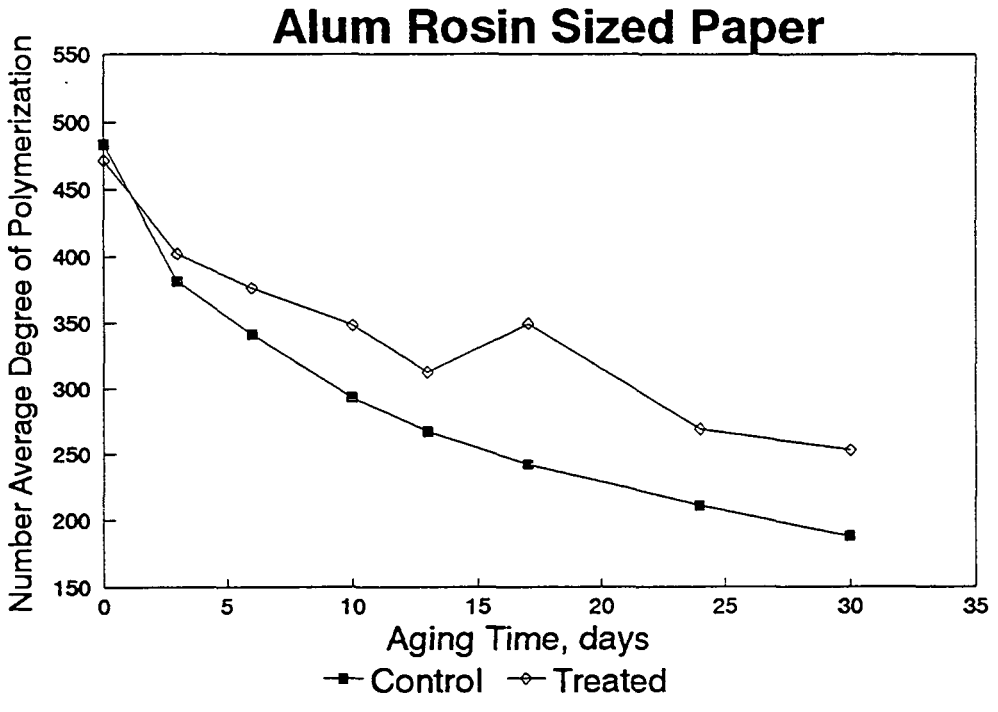

Fig. 4-AR Effect of Aging Time on No Average Degree of Polymerization.

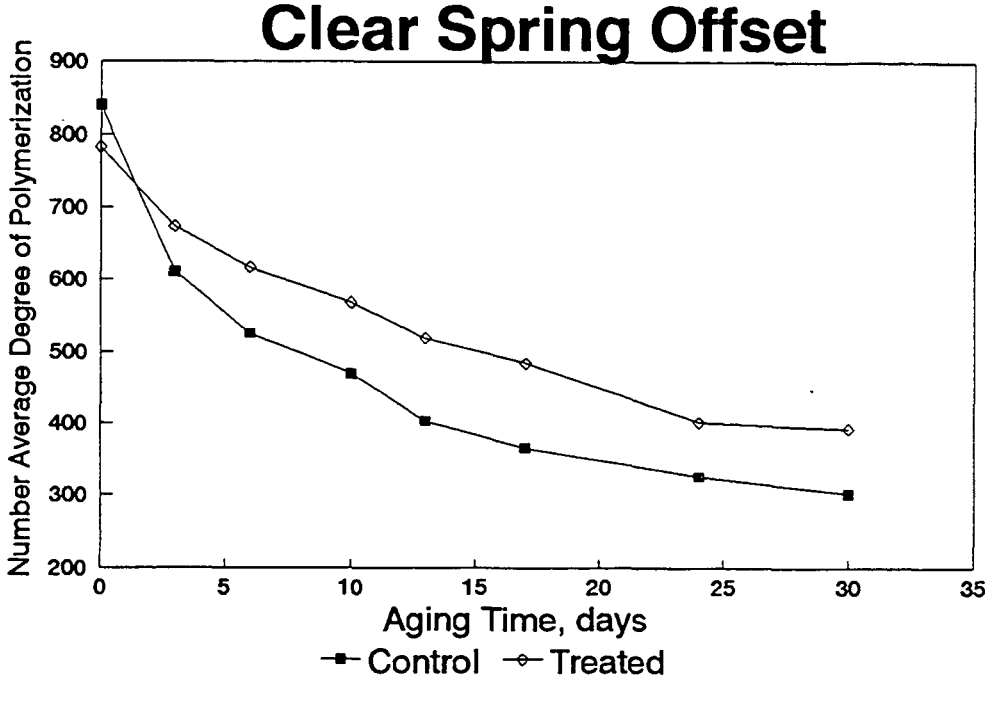

Fig. 4-CS Effect of Aging Time on No Average Degree of Polymerization.

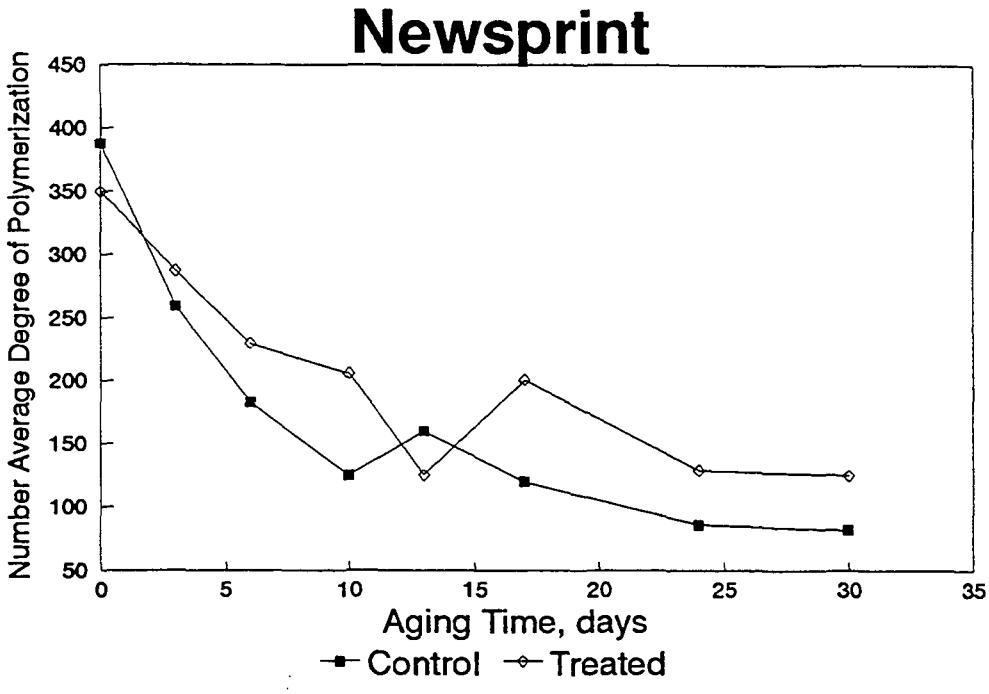

Fig. 4-NP Effect of Aging Time on No Average Degree of Polymerization.

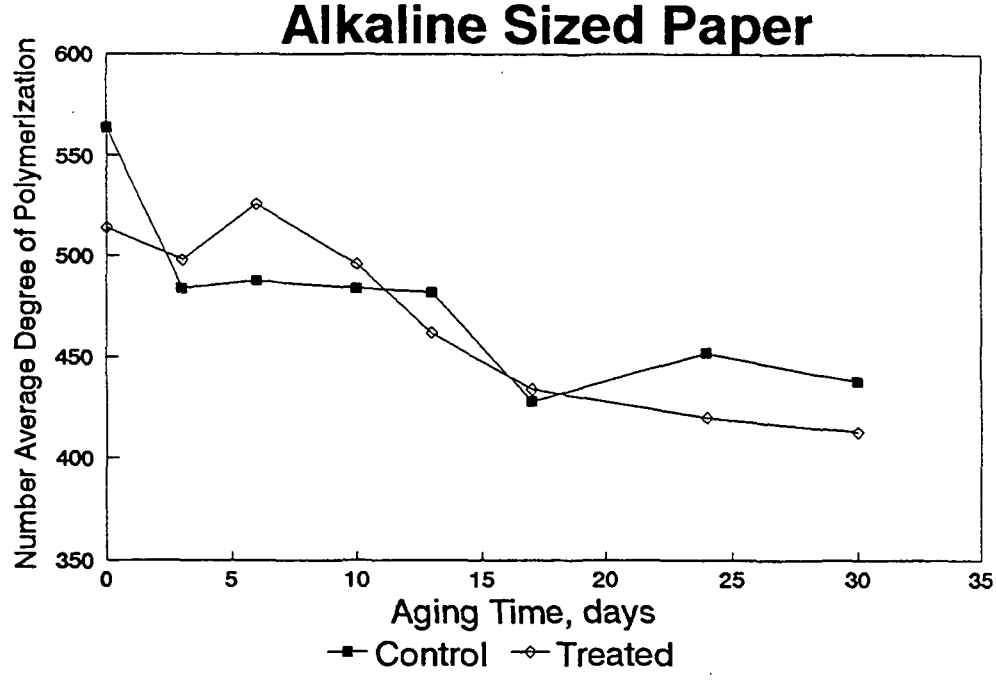

Fig. 4-AS Effect of Aging Time on No Average Degree of Polymerization.

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TABLE I

MD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
0	1	805	960	1083	1196	604	1340	N	N
	2	974	805	1580	779	211	1863	O	O
	3	1175	792	1287	1450	511	454		
	4	1147	1260	787	1393	1021	1160	S	S
	5	1424	844	1185	933	464	1486	A	A
	6	802	1089	942	1199	736	1238	M	M
	7	1018	829	1468	974	313	1464	P	P
	8	709	805	1253	1227	1262	940	L	L
	9	1031	766	1177	1382	697	1013	E	E
	10	889	1367	1085	1411	1252	2065		
	Average	997	952	1185	1194	707	1302		
	Std Dev	202	204	221	219	348	438		

CD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
0	1	348	493	314	214	154	286	N	N
	2	361	278	466	387	91	246	O	O
	3	395	349	282	379	225	46		
	4	139	311	336	406	152	384	S	S
	5	240	176	333	329	216	280	A	A
	6	340	446	603	306	81	223	M	M
	7	266	546	316	295	465	335	P	P
	8	84	430	244	147	117	367	L	L
	9	371	406	384	250	95	111	E	E
	10	263	273	306	322	601	71		
	Average	281	371	358	304	220	235		
	Std Dev	98	108	99	77	166	115		

TABLE I (cont)

MD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
3	1	459	487	666	561	534	382	N	N
	2	742	615	770	609	450	750	O	O
	3	473	400	657	596	1260	1427		
	4	429	887	691	1072	667	455	S	S
	5	456	808	438	616	617	1209	A	A
	6	876	997	658	541	355	975	M	M
	7	622	579	430	778	499	1382	P	P
	8	458	689	803	556	1038	900	L	L
	9	577	732	859	818	1101	768	E	E
	10	454	612	685	743	1400	1389		
	Average	555	681	666	689	792	964		
	Std Dev	143	172	133	158	354	363		

CD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
3	1	190	76	257	335	168	126	N	N
	2	211	274	208	334	52	293	O	O
	3	213	260	333	277	133	117		
	4	251	438	248	318	210	398	S	S
	5	188	372	187	143	100	328	A	A
	6	187	342	249	290	185	170	M	M
	7	190	323	226	133	230	410	P	P
	8	393	272	275	168	166	195	L	L
	9	221	252	234	246	254	103	E	E
	10	202	279	319	236	93	796		
	Average	225	289	254	248	159	294		
	Std Dev	59	90	43	73	61	200		

TABLE I (cont)

MD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
6	1	269	453	355	1313	531	376	N	N
	2	324	466	398	1167	438	323	O	O
	3	310	468	218	798	862	1394		
	4	449	480	332	898	303	938	S	S
	5	322	330	529	635	444	914	A	A
	6	475	482	295	963	201	794	M	M
	7	355	667	355	728	698	1413	P	P
	8	301	400	286	1105	403	612	L	L
	9	314	574	418	1038	615	733	E	E
	10	502	337	449	908	408	891		
	Average	362	466	364	955	490	839		
	Std Dev	78	96	85	197	183	347		

CD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
6	1	209	191	152	363	59	180	N	N
	2	349	241	143	377	65	661	O	O
	3	298	283	238	489	112	97		
	4	307	147	171	328	85	66	S	S
	5	175	243	222	350	277	212	A	A
	6	362	274	122	342	37	513	M	M
	7	274	268	107	305	100	381	P	P
	8	225	192	174	366	170	650	L	L
	9	176	254	131	311	61	340	E	E
	10	282	226	200	362	47	298		
	Average	266	232	166	359	101	340		
	Std Dev	64	41	41	49	69	202		

TABLE I (cont)

MD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
10	1	65	556	42	550	176	816	N	N
	2	264	445	65	557	250	1070	O	O
	3	85	592	45	868	293	511		
	4	154	371	109	884	107	984	S	S
	5	301	507	82	635	324	399	A	A
	6	149	350	41	848	146	625	M	M
	7	260	224	30	786	336	1183	P	P
	8	130	466	103	806	132	981	L	L
	9	107	444	34	661	287	608	E	E
	10	388	780	86	656	371	780		
	Average	190	474	64	725	242	796		
	Std Dev	101	143	28	121	90	245		

CD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
10	1	59	234	109	157	39	264	N	N
	2	64	168	66	148	39	162	O	O
	3	114	233	91	136	42	235		
	4	91	177	73	151	100	82	S	S
	5	116	176	99	113	54	229	A	A
	6	117	95	57	225	31	350	M	M
	7	73	226	87	237	124	197	P	P
	8	105	198	88	122	34	119	L	L
	9	56	213	84	310	187	64	E	E
	10	86	274	75	231	201	92		
	Average	88	199	83	183	85	179		
	Std Dev	23	47	15	61	62	87		

TABLE I (cont)

MD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
13	1	53	280	8	434	265	326	N	N
	2	50	497	9	642	251	524	O	O
	3	28	330	9	356	217	366		
	4	47	274	9	697	127	637	S	S
	5	59	670	8	439	340	416	A	A
	6	20	229	8	391	442	326	M	M
	7	31	377	8	632	72	250	P	P
	8	40	332	9	628	42	483	L	L
	9	23	268	8	365	178	816	E	E
	10	83	394	9	668	114	834		
	Average	43	365	9	525	205	498		
	Std Dev	18	125	1	132	118	195		

CD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
13	1	58	98	47	149	56	258	N	N
	2	41	138	29	147	56	81	O	O
	3	73	276	34	124	78	76		
	4	41	190	30	104	79	227	S	S
	5	67	263	37	241	120	150	A	A
	6	115	128	33	272	21	275	M	M
	7	157	294	19	229	77	227	P	P
	8	37	136	27	204	26	151	L	L
	9	32	112	36	177	82	141	E	E
	10	95	159	26	212	36	144		
	Average	72	179	32	186	63	173		
	Std Dev	38	69	7	52	29	66		

TABLE I (cont)

MD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
17	1	14	287	8	536	270	368	N	N
	2	13	279	6	491	413	1031	O	O
	3	14	243	6	606	259	414		
	4	9	328	4	580	300	183	S	S
	5	10	198	5	483	137	733	A	A
	6	11	347	4	337	398	472	M	M
	7	15	290	4	428	364	918	P	P
	8	11	734	4	499	230	539	L	L
	9	19	221	4	464	248	548	E	E
	10	7	255	4	456	484	847		
	Average	12	318	5	488	310	605		
	Std Dev	3	145	1	73	98	255		

CD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
17	1	47	301	30	171	51	47	N	N
	2	27	278	25	195	50	212	O	O
	3	44	167	31	110	16	56		
	4	26	161	40	107	45	101	S	S
	5	38	109	36	320	42	83	A	A
	6	30	155	25	211	49	112	M	M
	7	33	212	31	160	86	360	P	P
	8	49	197	26	183	78	108	L	L
	9	24	115	26	106	58	295	E	E
	10	24	136	25	198	37	161		
	Average	34	183	30	176	51	154		
	Std Dev	9	61	5	61	19	99		

TABLE I (cont)

MD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
25	1	2	98	1	415	26	490	N	N
	2	3	130	1	344	49	77	O	O
	3	3	224	1	279	45	274		
	4	3	245	1	249	45	138	S	S
	5	4	280	1	672	23	128	A	A
	6	3	222	1	330	48	290	M	M
	7	3	139	1	343	91	751	P	P
	8	2	209	1	462	30	476	L	L
	9	2	187	1	299	77	563	E	E
	10	2	222	1	329	27	429		
	Average	3	196	1	372	46	362		
	Std Dev	1	54	0	116	21	206		

CD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
25	1	5	73	6	140	16	52	N	N
	2	3	200	8	150	20	30	O	O
	3	3	57	9	110	11	179		
	4	3	89	16	158	30	189	S	S
	5	4	51	13	106	20	71	A	A
	6	6	35	2	132	8	148	M	M
	7	3	92	2	186	11	173	P	P
	8	4	88	2	139	12	116	L	L
	9	8	47	4	208	19	215	E	E
	10	5	40	6	184	12	132		
	Average	4	77	7	151	16	131		
	Std Dev	2	46	5	32	6	59		

TABLE I (cont)

MD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
31	1	1	183	1	157	64	303	N	N
	2	1	108	1	123	22	247	O	O
	3	1	188	1	170	22	239		
	4	2	101	1	139	24	149	S	S
	5	0	151	1	267	45	457	A	A
	6	1	223	1	82	48	458	M	M
	7	0	291	2	154	60	201	P	P
	8	2	303	1	88	46	142	L	L
	9	1	241	1	134	93	119	E	E
	10	1	244	1	181	49	391		
	Average	1	203	1	150	47	271		
	Std Dev	1	66	0	50	21	121		

CD MIT FOLD DATA (double folds) AT 1/2 KG TENSION

Aging Time, days	Test No.	ARC	ART	CSC	CST	NPC	NPT	ASC	AST
31	1	4	144	2	111	9	148	N	N
	2	3	93	2	125	11	150	O	O
	3	3	117	1	127	8	330		
	4	2	152	1	138	12	185	S	S
	5	2	66	1	98	12	71	A	A
	6	3	89	2	143	8	119	M	M
	7	2	125	2	123	9	73	P	P
	8	2	60	2	104	10	154	L	L
	9	3	92	2	77	19	97	E	E
	10	2	77	2	84	7	50		
	Average	3	102	2	113	11	138		
	Std Dev	1	30	0	21	3	76		